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Concentrations of Radionuclides and Trace Elements in Environmental Media Around the Dual-Axis Radiographic Hydrodynamic Test Facility at Los Alamos National Laboratory



Edited by Hector Hinojosa, Group IM-1

Cover illustration: Soil, vegetation, birds, bees, and small mammals are monitored at the DARHT facility on a regular basis.

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Concentrations of Radionuclides and Trace Elements
in Environmental Media around the Dual-Axis
Radiographic Hydrodynamic Test Facility at
Los Alamos National Laboratory during 2005

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Contents

EXECUTIVE SUMMARY.....	IX
ABSTRACT.....	1
I. INTRODUCTION.....	2
II. METHODS AND MATERIALS	2
<i>a. Estimating Total Propagated Analytical Uncertainty for Radiometric Analyses</i>	<i>2</i>
<i>b. Determining the Composition of Uranium</i>	<i>4</i>
REFERENCES	5
Soils and Sediment.....	7
ABSTRACT.....	7
I. INTRODUCTION.....	7
II. METHODS AND MATERIALS	7
<i>a. Soil and Sediment Sampling.....</i>	<i>7</i>
<i>b. Soil Standards</i>	<i>9</i>
III. RESULTS	10
<i>a. Surface Soils and Sediments</i>	<i>10</i>
IV. CONCLUSIONS	12
ACKNOWLEDGMENTS	12
REFERENCES	14
Vegetation	17
ABSTRACT.....	17
I. INTRODUCTION.....	17
II. METHODS AND MATERIALS	17
<i>a. Vegetation Sampling.....</i>	<i>17</i>
<i>b. Plant Standards</i>	<i>19</i>
III. RESULTS	20
<i>a. Vegetation Samples</i>	<i>20</i>
ACKNOWLEDGMENTS	23
REFERENCES	23
Honey Bees	25
ABSTRACT.....	25
I. INTRODUCTION.....	25
II. METHODS	26
<i>a. Bee Sampling</i>	<i>26</i>

<i>b. Analytical Methods</i>	26
<i>c. Biota Standards</i>	28
III. RESULTS	28
REFERENCES	31
Bird Monitoring Near DARHT in 2003, 2004, and 2005	33
ABSTRACT.....	33
I. INTRODUCTION.....	33
II. METHODS.....	33
III. RESULTS	35
ACKNOWLEDGMENTS.....	35
REFERENCES	35
The Effects of Discontinuity in Sample Data	39
ABSTRACT.....	39
I. INTRODUCTION.....	39
II. METHODS.....	40
III. RESULTS	41
IV. DISCUSSION.....	43
V. CONCLUSIONS.....	45
REFERENCES	45

List of Figures

Soils and Sediment

Figure 1. Sampling areas at DARHT at TA-15.....	8
---	---

Vegetation

Figure 1. Sampling areas at DARHT at TA-15.....	18
---	----

Honey Bees

Figure 1. Location of the beehives near DARHT.....	27
--	----

Bird Monitoring near DARHT in 2003, 2004, and 2005

Figure 1. DARHT net locations.....	34
------------------------------------	----

List of Tables

Soils and Sediment

Table 1. Application of Soil Standards and Other Reference Levels to DARHT Monitoring Data.....	10
Table 2. Radionuclide Concentrations (Analytical Uncertainty at Three Sigma) in Surface Soil and Sediment Collected around the DARHT Facility in 2005.....	11
Table 3. Total Trace Element Concentrations ($\mu\text{g/g}$ dry) in Surface Soil and Sediment Collected around the DARHT Facility in 2005	13

Vegetation

Table 1. Application of Vegetation Standards and Other Reference Levels to DARHT Monitoring Data.....	20
Table 2. Radionuclide Concentrations (Analytical Uncertainty at Three Sigma) in Overstory and Understory Vegetation Collected around the DARHT Facility in 2005.....	21
Table 3. Total Trace Element Concentrations ($\mu\text{g/g}$ dry) in Overstory and Understory Vegetation Collected around the DARHT Facility in 2005.....	22

Honey Bees

Table 1. Radionuclide Concentrations (Analytical Uncertainty at Three Sigma) in Honey Bees Collected from Hives near DARHT in 2005.....	29
Table 2. Trace Element Concentrations (mg/kg wet) in Honey Bees Collected from Hives near DARHT in 2005	30

Bird Monitoring near DARHT in 2003, 2004, and 2005

Table 1. Birds Captured in 2003.....	36
Table 2. Birds Captured in 2004.....	37
Table 3. Birds Captured in 2005.....	38

Effects of Discontinuity

Table 1. Media Sampling Occurrences by Year for the DARHT Facility Conducted Under the MAP	40
Table 2. Results in Analysis of Variance Tests for Significance of Differences in Mean Radionuclide Concentrations Between Years	42
Table 3. Results in Analysis of Variance Tests for Significance of Differences in Mean Radionuclide Concentrations Between Sampling Locations	42

EXECUTIVE SUMMARY

The Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at the Los Alamos National Laboratory (LANL) is the Laboratory's principal explosive test facility. In 1995, as required by the National Environmental Policy Act (NEPA), the U.S. Department of Energy (DOE) published a Final Environmental Impact Statement (EIS) concerning the DARHT facility. The Final EIS identified measures that DOE considered to mitigate potential adverse effects resulting from the various alternatives promulgated in the Draft EIS. A Record of Decision (ROD) on the EIS established several mitigation measures to protect soils, water, and biotic and cultural resources. The DOE agreed to also take special precautions to protect the Mexican spotted owl (*Strix occidentalis lucida*). As required following the completion of an EIS, a Mitigation Action Plan (MAP) was developed describing how the corresponding mitigation measures were to be implemented to meet the commitments made in the ROD. As a component of the MAP, LANL has been measuring radionuclide and inorganic chemical concentrations in five environmental media (soil, plants, bees, birds, and small mammals) around the DARHT facility since 1996. Up to four years (1996–1999) of preoperational baseline data have been collected and up to six years (2000, 2001, and 2003–2005) of postoperational data have been collected. Each year LANL produces a MAP annual report and media-based technical reports. Covering calendar year 2005, technical reports on soil, vegetation, bees, and one special report have been compiled into this compendium. Bird population data for 2003–2005 are included in this report and bird contaminant for the same three years will be included in next year's report. The monitoring is conducted to determine whether there are any environmental impacts in terms of increases in levels of contaminants, and, periodically, potential health impacts to humans and/or biota are estimated.

Samples of soil, sediment, and unwashed overstory and understory vegetation were collected at four locations around the facility in 2005 and analyzed for concentrations of ^3H , ^{137}Cs , ^{90}Sr , ^{238}Pu , $^{239,240}\text{Pu}$, ^{241}Am , ^{234}U , ^{235}U , ^{238}U , Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl. These results, which represent six sample periods since the start of operations, were compared with (1) baseline statistical reference levels (BSRLs) established over a four-year preoperational period prior to DARHT facility operations, (2) screening levels (SLs), and (3) regulatory standards. Most radionuclides and trace elements in soil, sediment, and vegetation were below BSRLs and those few samples that contained radionuclides and trace elements above BSRLs were below SLs. Overstory plants had U ratios consistent with depleted U; but overall, concentrations of radionuclides and nonradionuclides in biotic and abiotic media around the DARHT facility do not pose a significant human health hazard.

Honey bee samples were collected from five hives placed downwind of the DARHT facility. Samples were analyzed for various radionuclides and trace

elements and compared to BSRLs. Most concentrations of radionuclides and all nonradionuclides were below the BSRLs. The only radionuclides that were above the BSRLs were those associated with U, particularly ^{238}U , and the ratios showed that the U was of depleted grade. All concentrations of U isotopes, however, were still very low—below terrestrial animal dose screening levels (<0.01 rad/d) and, therefore, not a significant hazard.

The number of birds captured and number of species, respectively, were 164 and 29 for 2003, 126 and 28 for 2004, and 412 and 46 for 2005. The chipping sparrow (*Spizella passerina*) was a commonly captured species for all three years.

The DARHT facility MAP requires collection of data on the five media each year for the 30-year estimated life of the facility. Because interruptions have occurred in the collection of samples for various reasons, DARHT facility project managers were interested in knowing the effects of discontinuity in the sample data on the use of the data and on the ability to meet the intent of the MAP. We analyzed postoperational radionuclide data for statistical differences between years and, for media where data have been collected in more than one location, we also analyzed for statistical differences between locations. As a measure of whether substantial differences might exist in outcomes of using the data from different media, we also estimated radiation dose to the Mexican spotted owl that could result from using two different starting points (or contaminant sources) in the food pathway leading to the owl: (1) beginning with radionuclide concentrations in deer mice versus (2) beginning with radionuclide concentrations in understory vegetation. On the basis of several criteria, periodic interruption of the scope and schedule identified in the MAP generally should have no impact on meeting the purpose and goals of the MAP. It is most important to continue sampling soils, vegetation, and small mammals as uninterrupted as possible. The large home range of bees conveys information on contaminant levels over a much broader area than most of the other sampling media. Since the MAP is a requirement that was established under the regulatory framework of NEPA, any changes to the monitoring requirements in the MAP must be negotiated and ultimately approved by the DOE.

Concentrations of Radionuclides and Trace Elements in Environmental Media around the Dual-Axis Radiographic Hydrodynamic Test Facility at Los Alamos National Laboratory during 2005

by

G. J. Gonzales, P. R. Fresquez, C. D. Hathcock, and D. C. Keller

ABSTRACT

The Mitigation Action Plan (MAP) for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory requires that samples of biotic and abiotic media be collected after operations began to determine if there are any human health or environmental impacts. The DARHT facility is the Laboratory's principal explosive test facility. To this end, samples of soil and sediment, vegetation, bees, and birds were collected around the facility in 2005 and analyzed for concentrations of ^3H , ^{137}Cs , ^{90}Sr , ^{238}Pu , $^{239,240}\text{Pu}$, ^{241}Am , ^{234}U , ^{235}U , ^{238}U , Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl. Bird populations have also been monitored. Contaminant results, which represent up to six sample years since the start of operations, were compared with (1) baseline statistical reference levels (BSRLs) established over a four-year preoperational period before DARHT facility operations, (2) screening levels (SLs), and (3) regulatory standards. Most radionuclides and trace elements were below BSRLs and those few samples that contained radionuclides and trace elements above BSRLs were below SLs. Concentrations of radionuclides and nonradionuclides in biotic and abiotic media around the DARHT facility do not pose a significant human health hazard. The total number of birds captured and number of species represented were similar in 2003 and 2004, but both of these parameters increased substantially in 2005. Periodic interruption of the scope and schedule identified in the MAP generally should have no impact on meeting the intent of the MAP. The risk of not sampling one of the five media in any given year is that if a significant impact to contaminant levels were to occur there would exist a less complete understanding of the extent of the change to the baseline for these media and to the ecosystem as a whole. Since the MAP is a requirement that was established under the regulatory framework of the National Environmental Policy Act, any changes to the monitoring requirements in the MAP must be negotiated with and ultimately approved by the U.S. Department of Energy.

I. INTRODUCTION

The US Department of Energy (DOE) prepared and issued a Mitigation Action Plan (MAP) for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility in response to a Record of Decision (USDOE 1995a) for the DARHT Environmental Impact Statement (USDOE 1995b). The DARHT MAP documents, in part, the DOE's commitment to protect natural and cultural resources during the construction, operation, and decommissioning phases of the DARHT facility (USDOE 1996). One of the initial tasks identified in section VIII.A.1(a) of the MAP mandates measurement of baseline concentrations of radioactive and stable materials through the collection and analysis of soils, invertebrates, plants, mammals, birds, and animals killed accidentally on Los Alamos National Laboratory roads near the DARHT facility during the construction phase.

A final report was issued in 2001 (Nyhan et al., 2001) summarizing all of these environmental data collected during the construction phase (1996 through 1999) and before any operational events, thus establishing baseline statistical reference levels (BSRLs) for potential environmental contaminants in soils, sediments, vegetation, small mammals, birds, and bees at the DARHT facility. Covering calendar year 2005, technical reports on soil and sediment, vegetation, bees, and bird populations, and one special report addressing the importance of continuity of annual monitoring have been compiled here. This monitoring is conducted to determine whether there are any environmental impacts in terms of increases in levels of contaminants. Also, potential health impacts to humans and/or biota are periodically estimated.

II. METHODS AND MATERIALS

a. Estimating Total Propagated Analytical Uncertainty for Radiometric Analyses

Radioanalytical data reporting convention includes estimates of analysis uncertainty. This procedure provides estimates of uncertainties throughout the radiochemical preparation and counting process, such that the reported uncertainty includes all known sources of potential error. Estimates of uncertainties in various significant steps of radioanalytical procedures are established, either by the collection of empirical data or by use of reliable standards, such as the American National Standards Institute N42 standards (ANSI 1989). These include uncertainty

estimates in volume and mass determinations, process reproducibility, instrument calibration and operation, and counting uncertainty.

Estimated uncertainties may be calculated either in activity units (e.g., pCi/g) or as a relative uncertainty (e.g., a percentage of the measured activity). By convention, any uncertainty calculated as a relative value must be multiplied by the sample activity, thereby converting the value to activity units, before using that uncertainty component in the final calculation.

Total propagated analytical uncertainty (TPU) is defined (Paragon Analytics, Inc., 2002) as:

$$\text{TPU} = (\text{CU}^2 + \text{YU}^2 + \text{IU}^2 + \text{PU}^2)^{0.50} \quad (\text{Eq. 1})$$

where

CU = analyte count rate uncertainty,

YU = chemical yield determination uncertainty,

IU = instrument analysis uncertainty, and

PU = chemical preparation uncertainty.

The analyte count rate uncertainty is the estimated deviation of the observed count rate from the true mean count rate of the analyte of interest. This component of TPU is due solely to the statistically random nature of radioactive decay.

Chemical yield determination uncertainties will vary considerably, depending on the method used to quantify the chemical yield of a given separation procedure. Chemical yields may be determined by the analysis of a radioactive tracer added to the sample before chemical separation. The method for estimating the uncertainty associated with a radiometric tracer measurement is identical to the analyte count rate uncertainty, except that the tracer counts are used instead of the counts for the analyte of interest. Chemical yields may be determined by the measurement of the residual mass of prepared sample deposited onto a planchet or filter. In this case, the error in the yield determination may be significantly affected by interfering chemical constituents native to the sample, which the lab has no control over. The uncertainty in a gravimetric yield determination is conservatively estimated at 10% of the measured sample activity.

Estimates of instrument analysis uncertainty of radiochemical samples are assumed to be as follows:

- calibration (in-house preparation of standards): 5%;
- calibration (vendor-prepared standards): 1.5%;
- counting reproducibility: 1%;
- sample position reproducibility: 1.5%;
- counting efficiency: 1.5%; and
- dead time estimates: 1%.

Estimates of chemical preparation uncertainty of radiochemical samples are as follows (some factors have been empirically determined):

- gross aliquoting (sample homogeneity): 5%;
- quantitative transfers: 2.5%;
- spike or tracer standard: 2.5%;
- aliquoting: 0.4%;
- volumetric measurements (non-volumetric lab ware): 0.6%;
- mass measurements: 0.3%;
- reagent addition (repipetting): 0.6%;
- aliquoting and Inductively Coupled Plasma yield determinations: 8.3%; and
- gravimetric yield determinations: 10%.

As described above, the estimated preparation uncertainties are combined, or propagated, together by calculating the square root of the sum of squares of all the individual uncertainties (Equation 1). This technique of combining uncertainties is also known as “summing in quadrature.” TPUs are subsequently reported at a multiplier of the sigma value (three-sigma) or at a specific confidence interval (99%). A detectable concentration was considered to be a result that was greater than three times the TPU. For the purpose of this compendium, the analytical uncertainty is reported at three times the TPU.

b. Determining the Composition of Uranium

To determine the source of U in the environmental media at the 99% confidence level, the U isotopic distribution of ^{234}U and ^{238}U , which for naturally occurring U is 1, was assessed

using the following steps: (1) the difference between ^{234}U and ^{238}U was calculated, (2) the squares of their uncertainties were summed and then the square root of this number was taken, (3) the ^{234}U and ^{238}U difference was divided by the pooled square root, (4) if the result was greater than 3, then it was observed whether the ^{234}U value or the ^{238}U value was larger, (5) if the ^{234}U value was larger, then excess enriched U was indicated. Conversely, if the ^{238}U value was larger, then excess depleted U was indicated.

REFERENCES

ANSI (American National Standards Institute), "Performance Specifications for Health Physics Instrumentation—Portable Instruments for Use in Normal Environmental Conditions," ANSI N42.17A Washington, DC (1989).

Nyhan, J.W., P.R. Fresquez, K.D. Bennett, J.R. Biggs, T.K. Haarmann, D.C. Keller, and H.T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility; Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001).

Paragon Analytics, Inc., "Estimating Total Propagated Uncertainty for Radiometric Analyses," Standard Operating Procedure 743, Revision 4 (03/02/02), Fort Collins, CO (2002).

USDOE (US Department of Energy), "Dual-Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement Record of Decision," United States Department of Energy report USDOE/EIS-0228 (1995a).

USDOE (US Department of Energy), "Final Environmental Impact Statement: Dual-Axis Radiographic Hydrodynamic Test Facility," United States Department of Energy report USDOE/EIS-0228 (1995b).

USDOE (US Department of Energy), "Dual-Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement Mitigation Action Plan," United States Department of Energy report USDOE/EIS-0228 (1996).

Soils and Sediment

by

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ABSTRACT

Samples of soil and sediment were collected at four locations around the facility in 2005 and analyzed for concentrations of various radionuclides and trace elements. These results represent six sample periods since the start of operations. Most radionuclides and trace elements in soil and sediment were below baseline statistical reference levels (BSRLs), and those few samples that contained radionuclides and trace elements above BSRLs were below screening levels.

I. INTRODUCTION

This section of the report addresses contaminants in soils and sediments. The objective of this monitoring study is to compare operation-period concentrations of radionuclides and trace elements in soils and sediments around the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility collected in 2005 with baseline statistical reference levels (BSRLs) as reported in Fresquez et al. (2001). These data reflect six years of monitoring since the beginning of operations in 2000.

II. METHODS AND MATERIALS

a. Soil and Sediment Sampling

Four composite soil surface samples were collected in April of 2005 with a stainless steel soil ring 10 cm (4 in.) in diameter driven 5 cm (2 in.) into the soil (ASTM 1990) approximately 24 m (80 ft) to 46 m (150 ft) away from the north, east, south, and west sides of the DARHT facility at Technical Area (TA) 15 (Fresquez 1996) (Figure 1).

At each site, samples of soil were collected from the center and corners of a square area 10 m (32 ft) per side; the five sub-samples were combined and mixed thoroughly in a three-gallon plastic resealable bag to form a composite sample. Four sediment grab samples were also collected at the 0- to 15-cm (0- to 6-in.) depth with a Teflon scoop within four drainage channel/ponding areas originating from the DARHT facility on the north, east, south, and

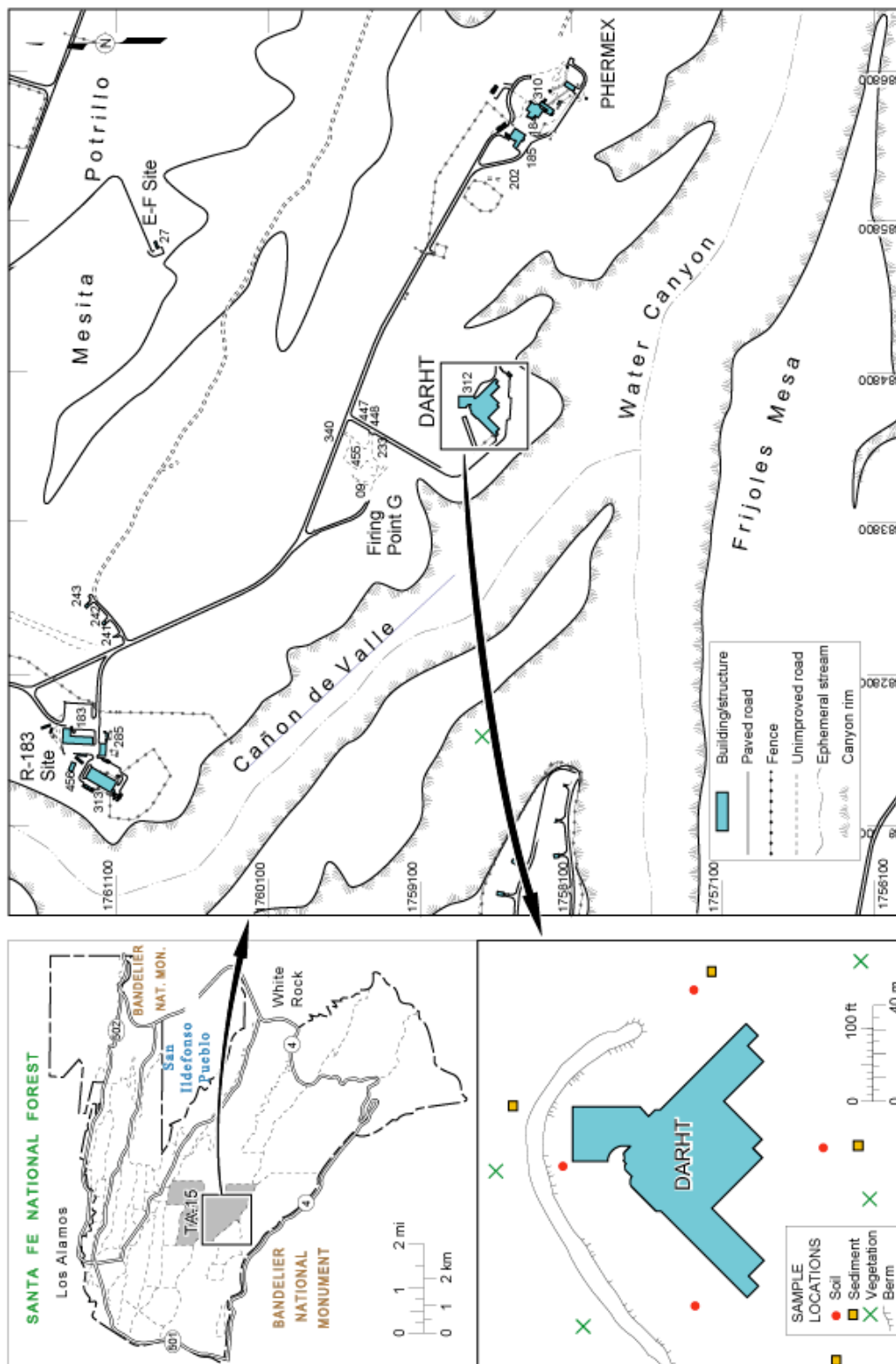


Figure 1. Sampling areas at DARHT at TA-15.

southwest sides. Most of the sediment material on the north side was a result of erosion off the berm wall; whereas, sediments from the other sites were from erosional processes off the grounds themselves.

All soil and sediment samples collected for radiological and trace element analyses were placed in prelabeled 500-mL polypropylene bottles. All containers were fitted with chain-of-custody tape, placed into individual plastic resealable plastic bags, transported in an ice chest cooled to approximately 4 °C, and submitted to Paragon Analytics, Inc., for the analysis of radionuclides (^3H , ^{137}Cs , ^{238}Pu , $^{239,240}\text{Pu}$, ^{90}Sr , ^{241}Am , and U isotopes) and trace elements (Ag, As, Ba, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, and Tl).

All methods of radionuclide analysis have been previously reported (Purtymun et al., 1987; Fresquez et al., 1996a, b; Nyhan et al., 2001a, b). Results are reported in pCi/mL (of soil moisture) for ^3H and pCi/g dry soil for all the other radioisotopes. The samples for trace elements were prepared for analysis based on SW-846. For the analysis of Ag, As, Ba, Be, Cd, Cr, Cu, Ni, Pb, Sb, Se, and Tl, the samples were digested following method 3050B and analyzed by trace Inductively Coupled Plasma by method 6010B. Mercury was analyzed by Cold Vapor Atomic Absorption after being digested by method 7471A. Other trace elements were reported on a $\mu\text{g/g}$ (ppm) dry weight basis.

b. Soil Standards

To evaluate DARHT facility impacts from radionuclides and nonradionuclides, the analytical results of soil samples collected from the facility are first compared to BSRLs. Where the levels exceed BSRLs, we then compare the concentrations to the screening levels (SLs). SLs are set below State and Federal Standards so that potential concerns may be identified in advance of problems (a “yellow flag”). If the level of a constituent exceeds a SL, then the reason for that increase is more thoroughly investigated. For radionuclides in soils, the SLs were developed by the Environmental Restoration Project at Los Alamos National Laboratory (LANL) to identify contaminants of concern (i.e., an investigative action level) on the basis of a conservative (e.g., hypothesized residential land use) 15-mrem protective dose limit (LANL/ER 2001). For nonradionuclides in soils, the SLs are based on the New Mexico Environment Department (NMED)/LANL Order on Consent, which is set at 10^{-5} risk (industrial/occupational)

(NMED/LANL 2005). Finally, if the level of a contaminant exceeds the SL then it is compared to the standard. For radionuclides in soils, the measured concentrations are used to calculate a per-person dose with the help of the RESRAD computer model (Yu et al., 1995). The calculated dose is based on a residential scenario and assumes soil ingestion, inhalation of suspended dust, and ingestion of homegrown fruits and vegetables as the primary exposure pathways for one or more radionuclides. The unit conversions, input parameters, model and parameter assumptions, and the uncertainty analysis that are used can be found in Fresquez et al. (1996b). This calculated per-person dose is compared to the 100-mrem/yr U.S. Department of Energy standard. Table 1 summarizes the levels and/or standards used to evaluate contaminants in the soil monitoring program at the DARHT facility.

Table 1. Application of Soil Standards and Other Reference Levels to DARHT Monitoring Data

Media	Constituent	Standard	Screening Level	Background
Soil	Radionuclides	100 mrem/y	15 mrem/y	BSRL
	Nonradionuclides		10 ⁻⁵ risk (industrial/occupational)	BSRL

III. RESULTS

Analytical reports for individual sample assays are stored in the Meteorology and Air Quality Group database and are available upon request.

a. Surface Soils and Sediments

Results of radionuclides in soils and sediments collected during 2005 are shown in Table 2. In general, all of the radionuclides in soils and sediments collected from around the DARHT facility are low (pCi range) and most, especially the sediment samples, contained radionuclide concentrations that were either nondetectable (i.e., results are lower than three times [the 99% confidence level] the total propagated analytical uncertainty TPU level) or below BSRL values.

Radionuclides that were above the BSRLs included concentrations of ¹³⁷Cs in three out of the four soil samples and one out of the four sediment samples, ^{239,240}Pu in one out of the four soil samples and one out of the four sediment samples, and most of the U isotopes in the soil samples. All of the soil and sediment samples had ratios consistent with natural U.

Table 2. Radionuclide Concentrations (Analytical Uncertainty at Three Sigma) in Surface Soil and Sediment Collected around the DARHT Facility in 2005^a (Note: Bold values are greater than both the TPU and BSRL.)

Location	³ H (pCi/mL) ^b	⁹⁰ Sr (pCi/g dry)	¹³⁷ Cs (pCi/g dry)	²³⁸ Pu (pCi/g dry)	^{239,240} Pu (pCi/g dry)	²⁴¹ Am (pCi/g dry)	²³⁴ U (pCi/g dry)	²³⁵ U (pCi/g dry)	²³⁸ U (pCi/g dry)
Soil									
North	0.05 (0.33)	0.059 (0.12)	0.23 (0.13)	-0.0018 (0.011)	0.014 (0.018)	0.0041 (0.011)	5.0 (1.3)	0.21 (0.12)	5.4 (1.4)
East	0.27 (0.33)	0.15 (0.11)	0.40 (0.17)	-0.0034 (0.012)	0.019 (0.021)	0.0067 (0.012)	2.2 (0.63)	0.19 (0.11)	2.6 (0.72)
South	0.22 (0.33)	0.19 (0.12)	0.47 (0.15)	-0.0033 (0.010)	0.015 (0.015)	0.018 (0.020)	2.7 (0.72)	0.11 (0.081)	2.9 (0.78)
West	0.14 (0.33)	0.20 (0.15)	0.52 (0.17)	-0.00040 (0.011)	0.027 (0.021)	0.0045 (0.012)	2.9 (0.78)	0.18 (0.10)	3.1 (0.81)
BSRL^c									
SL ^d	0.53 6,400	0.34 5.7	0.27 5.3	0.003 49	0.017 44	0.008 39	2.4 63	0.10 17	2.2 86
Sediment									
North	0.16 (0.33)	0.11 (0.14)	0.16 (0.093)	0.00040 (0.012)	0.010 (0.015)	0.0023 (0.014)	1.9 (0.54)	0.15 (0.090)	2.1 (0.57)
East	0.0 (0.32)	0.053 (0.13)	0.25 (0.12)	-0.0053 (0.011)	0.019 (0.018)	0.0069 (0.014)	1.9 (0.51)	0.10 (0.071)	2.2 (0.59)
South	0.14 (0.33)	0.078 (0.14)	0.91 (0.21)	0.0007 (0.011)	0.026 (0.023)	0.0089 (0.015)	2.3 (0.60)	0.11 (0.072)	2.3 (0.62)
Southwest	0.13 (0.33)	0.076 (0.14)	0.36 (0.12)	-0.0021 (0.011)	0.028 (0.023)	0.0077 (0.014)	2.3 (0.63)	0.15 (0.10)	2.3 (0.65)
BSRL^c									
SL ^d	0.90 6,400	0.26 5.7	0.51 5.3	0.005 49	0.026 44	0.015 39	3.7 63	0.16 17	3.3 86

^aSee Figure 1 for sample locations.

^bConcentration for ³H is based on soil moisture: a value of 6,400 is equivalent to a screening level value of 890 pCi/g ³H for a soil at a water content of 12%.

^cBaseline statistical reference level (Fresquez et al., 2001).

^dLos Alamos National Laboratory Screening Level (ER 2001).

These data exhibited similar results to past years in terms of the concentration levels (Nyhan et al., 2002; Fresquez et al., 2004; Fresquez 2004) and in that all values were far below SLs.

Therefore, the concentrations and distributions of all observed radionuclides in soils from all locations collected in 2005 are of no significant health concern.

Most trace elements in soil and sediment samples collected at the DARHT facility were below BSRLs (Table 3). The only metal that was above the BSRL was Pb in a sediment sample (16 µg/g) collected on the south side, but the amount was far below the SL of 750 µg/g and is of no health concern.

IV. CONCLUSIONS

Most radionuclides and trace elements in soils and sediments were within baseline data collected before operations at the DARHT facility. The few radionuclide and nonradionuclide elements in soils and sediments that were above preoperational concentrations do not pose a human health hazard.

ACKNOWLEDGMENTS

Thanks to Louis Naranjo for sample collection and processing.

Table 3. Total Trace Element Concentrations (µg/g dry) in Surface Soil and Sediment Collected around the DARHT Facility in 2005^a (Note: Bold values are greater than both the reporting limit and the BSRL.)

Location	Ag	As	Ba	Be	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Se	Tl
Soil													
North	U ^b	2.9	110	0.69	U	7.5	5.9	U	5.9	12	U	U	U
East	U	2.8	110	0.70	U	6.9	6.2	U	5.4	11	U	U	U
South	U	2.3	100	0.76	U	6.4	5.2	U	5.1	12	U	U	U
West	U	2.3	120	0.85	U	6.1	5.7	U	5.2	11	U	U	U
RL^c	0.57	0.57	0.23	0.23	0.28	0.57	0.57	0.012	1.1	0.17	0.45	0.28	0.45
BSRL^d	1.6	3.2	147	1.1	0.52	14	7.0	0.040	9.6	14	0.40	0.55	0.40
SL^e	5,680	18	7,830	2,250	8,600	3,400	45,400	341	22,500	750	454	5,680	75
Sediment													
North	U	3.1	140	0.88	U	7.0	6.7	U	5.9	12	U	U	U
East	U	2.6	110	0.68	U	7.1	4.4	U	5.1	9.7	U	0.38	U
South	U	2.7	120	0.82	U	6.5	7.7	0.017	5.4	16	U	U	U
Southwest	U	2.3	99	0.65	U	5.9	5.5	U	4.5	10	U	U	U
RL^c	0.57	0.57	0.23	0.23	0.28	0.57	0.57	0.012	1.1	0.17	0.45	0.28	0.45
BSRL^d	1.6	3.5	161	1.2	0.55	12	7.9	0.040	9.5	15	0.38	0.43	0.30
SL^e	5,680	18	7,830	2,250	8,600	3,400	45,400	341	22,500	750	454	5,680	75

^a See Figure 1 for sample locations.

^b Undetectable; the analyte was analyzed but not detected above the reporting limit.

^c Reporting Limit

^d Baseline Statistical Reference Level (Fresquez et al., 2001).

^e NMED Screening Level at 10⁻⁵ risk (industrial/occupational) (NMED/LANL 2005).

REFERENCES

- ASTM (American Society for Testing and Materials), "Standard Practice for Sampling Surface Soil for Radionuclides," in *Annual Book of ASTM Standards*, Philadelphia, PA (1990).
- Fresquez, P.R., "Study Plan for Soil, Plant, and Biota Contaminant Monitoring at DARHT," Los Alamos National Laboratory memorandum ESH-20/Ecol-96-0657 to Todd Haagenstad (1996).
- Fresquez, P.R., "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation Around the DARHT Facility during 2004," Los Alamos National Laboratory report LA-14176-PR (2004).
- Fresquez, P.R., D.R. Armstrong, and L. Naranjo, Jr., "Radionuclide and Heavy Metal Concentrations in Soil, Vegetation, and Fish Collected Around and Within Tsicoma Lake in Santa Clara Canyon," Los Alamos National Laboratory report LA-13144-MS (1996a).
- Fresquez, P.R., E.L. Vold, and L. Naranjo, Jr., "Radionuclide Concentrations in/on Vegetation at Radioactive-Waste Disposal Area G during the 1995 Growing Season," Los Alamos National Laboratory report LA-13124-PR (1996b).
- Fresquez, P.R., J.W. Nyhan, and H.T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, and Vegetation around the DARHT Facility," pp 13–40 in "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility; Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001).
- Fresquez, P.R., J.W. Nyhan, and E.L. Taylor, "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation Around the DARHT Facility during 2003," Los Alamos National Laboratory report LA-14099-PR (2004).
- LANL/ER (Los Alamos National Laboratory/Environmental Restoration), "Derivation and Use of Radionuclide Screening Action Levels," Los Alamos National Laboratory document LA-UR-01-990 (2001).
- NMED/LANL (New Mexico Environment Department/Los Alamos National Laboratory), "Compliance Order on Consent," New Mexico Environment Department, Santa Fe, NM (2005).
- Nyhan, J.W., P.R. Fresquez, K.D. Bennett, J.R. Biggs, T.K. Haarmann, D.C. Keller, and H.T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility; Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001a).
- Nyhan, J.W., P.R. Fresquez, H.T. Haagenstad, and W.R. Velasquez, "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation Around the DARHT Facility during 2000," Los Alamos National Laboratory report LA-13866-MS (2001b).
- Nyhan, J.W., P.R. Fresquez, H.T. Haagenstad, and W.R. Velasquez, "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation Around the DARHT Facility during 2001," Los Alamos National Laboratory report LA-13963-MS (2002).

Purtymun, W.D., R.J. Peters, T.E. Buhl, M.N. Maes, and F.H. Brown, "Background Concentrations of Radionuclides in Soils and River Sediment in Northern New Mexico, 1974–1986," Los Alamos National Laboratory report LA-11134-MS (1987).

Yu, C., A.J. Zielen, J.J. Cheng, T.C. Yuan, L.G. Jones, D.J. Lepoire, Y.Y. Wang, C.O. Loueiro, E. Gnanapragasam, J.E. Faillace, A. Wallo, III, W.A. Williams, and H. Peterson, "A Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.60," Argonne National Laboratory report ANL/EAD/LD-2 (1995).

Vegetation

by

P.R. Fresquez

ABSTRACT

Samples of unwashed overstory and understory vegetation were collected at four locations around the facility in 2005 and analyzed for various radionuclides and trace elements. These results represent six sample periods since the start of operations. Most radionuclides and trace elements in vegetation were below baseline statistical reference levels (BSRLs) and those few samples that contained radionuclides and trace elements above BSRLs were below screening levels. Some overstory plants had U ratios consistent with depleted U.

I. INTRODUCTION

This section of the report addresses contaminants in vegetation. The objective of this monitoring study is to compare operation-period concentrations of radionuclides and trace elements in vegetation around the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility collected in 2005 with baseline statistical reference levels (BSRLs) as reported in Fresquez et al. (2001). These data reflect six years of monitoring since the beginning of operations in 2000.

II. METHODS AND MATERIALS

a. Vegetation Sampling

Vegetation samples were collected from overstory (trees) and understory (grasses and forbs) plants in May of 2005 as close as possible to the soil sampling locations (Figure 1). Overstory samples, mostly ponderosa pine (*Pinus ponderosa*), consisted of tree-shoot tips approximately 5 cm to 10 cm (2 to 4 in.) in length at the 1.2- to 1.5-m (4- to 5-ft) height (Fresquez et al., 1996). One pine selected for overstory sampling was used as the center of the understory sample plot. Understory samples were collected from the corners and center of a 10- by 10-m (32- by 32-ft) square. Samples consisted of 0.9 to 1.4 kg (2 to 3 lb) of fresh, composited material and were double bagged in labeled plastic resealable plastic bags before transport to the

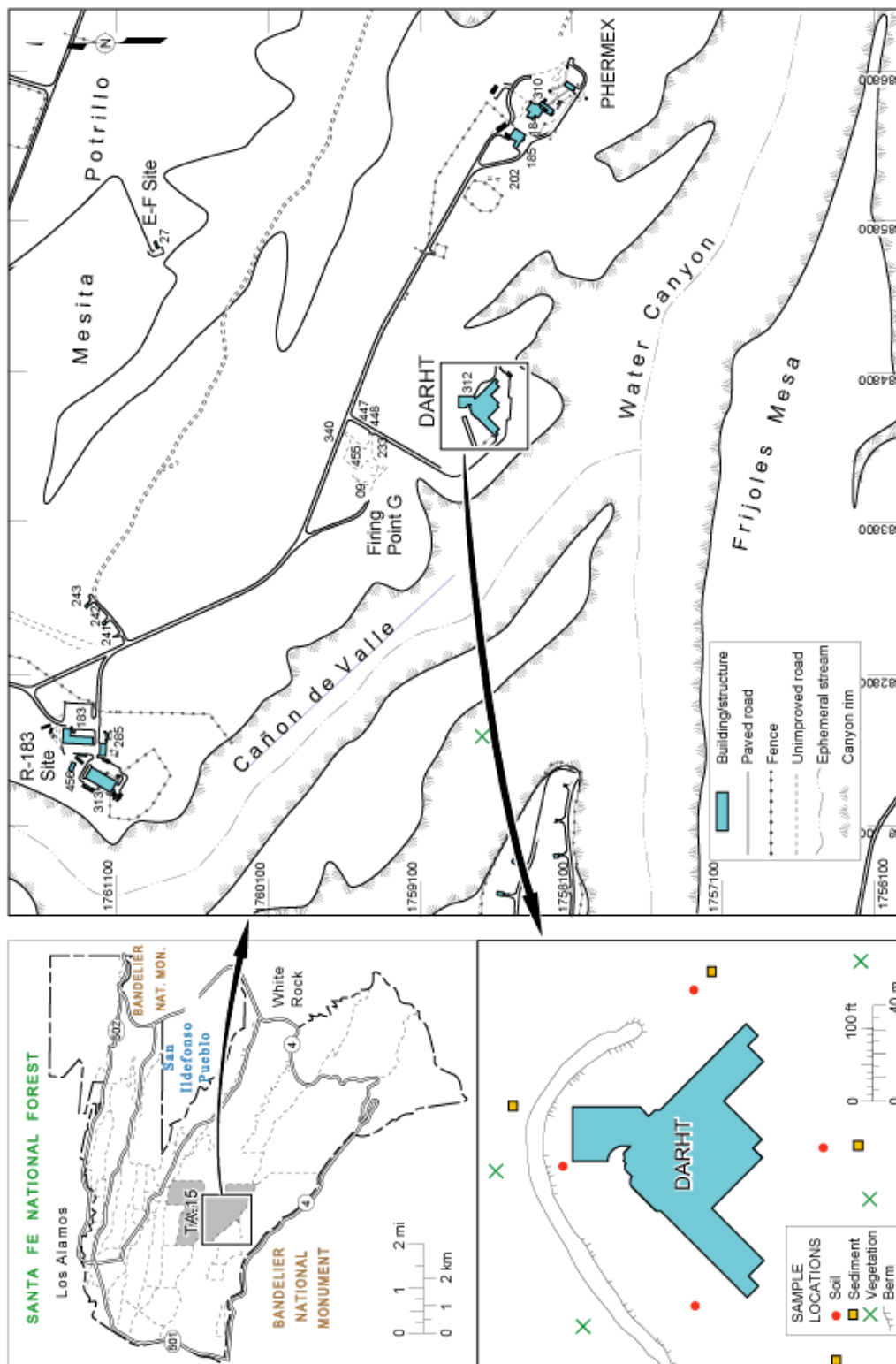


Figure 1. Sampling areas at DARHT at TA-15.

Meteorology and Air Quality (MAQ) Group laboratory at TA-21 in ice chests. At the laboratory, each unwashed sample was divided into three sub-samples for preparation and analyses of ^3H , other radionuclides, and trace elements.

Sub-samples for ^3H analysis were placed in an apparatus to collect distillate water (Salazar 1984). Vegetation sub-samples for trace element analysis were dried at 70 °C for 48 h then ground in a Wiley mill equipped with a 40-mm screen. The remaining portion of each sub-sample was placed into a 1-L glass beaker and ashed at 500 °C for at least 72 h. After ashing, the sample was then pulverized and homogenized, transferred to a labeled 500-mL polypropylene bottle, and, with the distillate samples, submitted under full chain-of-custody to Paragon Analytics, Inc., for the analysis of the same radionuclides and trace elements described in the soil section. Results were reported in pCi/mL of tissue moisture for ^3H and pCi/g of ash for the other radionuclides. Trace elements are reported in $\mu\text{g/g}$ dry.

b. Plant Standards

To evaluate DARHT facility impacts from radionuclides and nonradionuclides, the analytical results of plant samples collected from the facility are first compared to BSRLs. Where the levels exceed BSRLs, we then compare the concentrations to the screening levels (SLs). SLs are set below State and Federal Standards so that potential concerns may be identified in advance of problems (a “yellow flag”). If a constituent exceeds a SL, then the reason for that increase is more thoroughly investigated. For radionuclides in vegetation, the SLs were developed by the MAQ Group dose assessment team to identify the contaminants of concern at 10% of the standard. For nonradionuclides in vegetation, the SLs are based on toxicity values (TVs) from the literature.

Finally, if a contaminant exceeds the SL then it is compared to the standard. For radionuclides in vegetation, the measured concentrations are used to calculate a dose according to USDOE (2002) and compare it with the 1 rad/d dose standard for terrestrial plants. Table 1 summarizes the levels and/or standards used to evaluate the vegetation monitoring program at the DARHT facility.

Table 1. Application of Vegetation Standards and Other Reference Levels to DARHT Monitoring Data

Media	Constituent	Standard	Screening Level	Background
Vegetation	Radionuclides	1 rad/d	0.1 rad/d	BSRL
	Nonradionuclides		TVs	BSRL

III. RESULTS

Analytical reports for individual sample assays are stored in the MAQ Group database and are available upon request.

a. Vegetation Samples

Results of radionuclide concentrations in overstory and understory vegetation collected around the DARHT facility during 2005 can be found in Table 2. Most radionuclides, with the exception of ^{238}U in overstory vegetation, were either nondetectable or within BSRLs. All of the overstory vegetation samples collected around the DARHT facility contained ^{238}U concentrations just above the BSRL. The U in all of the overstory (and one understory) plants had ^{234}U and ^{238}U ratios consistent with that of depleted U and correlates well to last year's results (Fresquez 2004).

Results of the trace element concentrations in overstory and understory vegetation collected around the DARHT facility in 2005 can be found in Table 3. Concentrations of Ag, Be, Cd, Cr, Hg, Sb, Se, and Tl, for the most part, were below the reporting limits (i.e., they were undetected). Those that were detected above the reporting limits included As, Ba, Cu, Ni, and Pb; and of these, only As in overstory and understory plants and Cu in overstory plants were above the BSRLs. These two elements (As and Cu) have been detected in higher concentrations than the BSRLs in the past (Nyhan et al., 2003). Although the concentrations of As and Cu in plant tissues collected around the DARHT facility were above the BSRLs, they are below concentrations considered to be toxic to plant growth. Concentrations of As in plant tissues collected at DARHT (0.68 to 0.84 $\mu\text{g/g}$), for example, are below the range of 2.1 to 8.2 $\mu\text{g/g}$ considered toxic to plants (NRC 1977). Similarly, Cu, an essential plant micronutrient, in plant tissues from DARHT (7.5 to 12 $\mu\text{g/g}$) are within the recommended concentrations for adequate plant growth of 4 to 15 $\mu\text{g/g}$ (Stout 1961) and below the levels considered to be excessive (>22 $\mu\text{g/g}$) (Embleton et al., 1976; Stout 1961).

Table 2. Radionuclide Concentrations (Analytical Uncertainty at Three Sigma) in Overstory and Understory Vegetation Collected around the DARHT Facility in 2005^a (Note: Bold values are greater than both the total propagated analytical uncertainty and BSRL values.)

Location	³ H (pCi/mL) ^b	⁹⁰ Sr (pCi/g ash)	¹³⁷ Cs (pCi/g ash)	²³⁸ Pu (pCi/g ash)	^{239,240} Pu (pCi/g ash)	²⁴¹ Am (pCi/g ash)	²³⁴ U pCi/g ash	²³⁵ U pCi/g ash	²³⁸ U pCi/g ash
Overstory									
North	0.06 (0.45)	0.99 (0.35)	-0.06 (0.41)	0.0004 (0.0080)	0.0043 (0.0078)	0.0024 (0.0069)	0.36 (0.092)	0.041 (0.017)	1.6 (0.39)^c
East	0.37 (0.53)	5.2 (1.8)	-0.060 (0.59)	0.0023 (0.0066)	0.0 (0.0066)	0.0 (0.0063)	0.070 (0.18)	0.084 (0.029)	5.0 (1.2)^c
South	0.14 (0.44)	1.6 (0.56)	0.28 (0.66)	-0.0004 (0.0048)	0.0025 (0.0048)	0.0036 (0.0074)	0.26 (0.068)	0.019 (0.0098)	0.87 (0.21)^c
West	0.06 (0.53)	4.6 (1.7)	-0.01 (0.48)	-0.0005 (0.0059)	0.0036 (0.0065)	0.0012 (0.0069)	0.18 (0.051)	0.021 (0.011)	0.65 (0.17) ^c
BSRL^d	1.0	8.0	1.3	0.028	0.0060	0.016	0.73	0.031	0.65
Understory									
North	0.10 (0.47)	0.71 (0.26)	0.03 (0.78)	0.0006 (0.0062)	-0.0005 (0.0062)	0.0038 (0.0087)	0.055 (0.023)	0.0046 (0.0066)	0.073 (0.27)
East	0.19 (0.51)	1.2 (0.44)	0.19 (0.80)	-0.0014 (0.0056)	0.0001 (0.0056)	0.0043 (0.011)	0.10 (0.33)	0.0068 (0.0069)	0.42 (0.11)
South	0.34 (0.48)	1.4 (0.51)	0.14 (0.39)	-0.0009 (0.0056)	0.0010 (0.0056)	-0.0006 (0.0080)	0.054 (0.21)	0.0050 (0.0054)	0.052 (0.021)
West	0.40 (0.53)	1.2 (0.41)	-0.35 (0.69)	-0.0014 (0.0059)	-0.0009 (0.0059)	0.0039 (0.0092)	0.027 (0.015)	0.0062 (0.0077)	0.54 (0.021) ^c
BSRL^d	1.0	4.8	0.98	0.0040	0.013	0.011	1.1	0.045	0.96

^aSee Figure 1 for sample locations.

^bConcentration for ³H is based on moisture in vegetation.

^cIndicative of depleted U.

^dBaseline statistical reference level (Fresquez et al., 2001).

Table 3. Total Trace Element Concentrations (µg/g dry) in Overstory and Understory Vegetation Collected around the DARHT Facility in 2005^a (Bold values are greater than both the reporting limit and BSRLs.)

Location	Ag	As	Ba	Be	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Se	Tl
Overstory													
North	U ^b	0.81	6.3	U	U	0.50	10	U	U	5.5	U	U	U
East	U	0.69	35	U	U	U	9.0	U	1.2	3.7	U	U	U
South	U	0.68	14	U	U	U	7.5	U	U	3.0	U	U	U
West	U	0.76	60	U	1.4	0.82	12	U	1.5	6.7	U	U	U
RL^c	0.50	0.50	0.20	0.20	0.25	0.50	0.50	0.010	1.0	0.15	0.40	0.25	0.40
BSRL^d	1.0	0.28	68	0.13	0.56	1.0	4.6	0.060	5.0	6.1	8.6	0.35	0.27
SL^e		>2.1			>3.0		>22			>10			
Understory													
North	U	0.66	32	U	U	U	7.2	U	1.5	0.79	U	U	U
East	U	0.84	26	U	U	U	9.4	U	2.0	1.3	U	U	U
South	U	0.70	65	U	U	U	9.2	U	2.8	1.5	U	U	U
West	U	0.76	55	U	U	U	11	U	1.6	1.2	U	U	U
RL	0.50	0.50	0.20	0.20	0.25	0.50	0.50	0.010	1.0	0.15	0.40	0.25	0.40
BSRL^d	1.1	0.28	82	0.12	0.56	0.77	12	0.090	5.6	3.3	8.5	0.27	0.27
SL^e		>2.1											

^a See Figure 1 for sample locations.

^b Undetectable; the analyte was analyzed but not detected above the reporting limit.

^c Reporting Limit

^d Baseline statistical reference level (Fresquez et al., 2001).

^e Screening level for As based on NRC (1977), for Cd based on Allaway (1968), for Pb based on Stout (1961), and for Cu based on Embleton et al. (1976).

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REFERENCES

- Allaway, W.H., "Agronomic Controls over the Environmental Cycling of Trace Elements," pp. 235–274 in Norman, A.G., ed., *Advances in Agronomy*, v. 20, New York, Academic Press (1968).
- Embleton, T.W., W.W. Jones, and R.B. Platt, "Leaf Analysis as a Guide to Citrus Fertilization," pp. 4–9. in Reisenauer, H.M., ed., *Soil and Plant-Tissue Testing in California*: Univ. of Calif. Div. of Agr. Sci. Bull. 1879 (1976).
- Fresquez, P.R., "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation Around the DARHT Facility during 2004," Los Alamos National Laboratory report LA-14176-PR (2004).
- Fresquez, P.R., E.L. Vold, and L. Naranjo, Jr., "Radionuclide Concentrations in/on Vegetation at Radioactive-Waste Disposal Area G during the 1995 Growing Season," Los Alamos National Laboratory report LA-13124-PR (1996).
- Fresquez, P.R., J.W. Nyhan, and H.T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, and Vegetation around the DARHT Facility," pp 13–40 in "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility; Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001).
- NRC (National Research Council), "Committee on Biologic Effects of Atmospheric Pollutants, Arsenic," pp. 332. Washington National Academy of Science (1977).
- Nyhan, J.W., P.R. Fresquez, and E.L. Taylor, "Concentrations of Radionuclides and Trace Elements in Soils and Vegetation Around the DARHT Facility during 2002," Los Alamos National Laboratory report LA-14056-PR (2003).
- Salazar, J.G., "Produce and Fish Sampling Program of Los Alamos National Laboratory's Environmental Surveillance Group," Los Alamos National Laboratory report LA-10186-MS (1984).
- Stout, P.R., "Micronutrient Needs for Plant Growth," pp. 35–41 in *Proc. 9th Annual California Fertilizer Conferences*, California State Polytechnical Univ. Coop. Ext. Ser. Circ 433 (1961).
- USDOE (US Department of Energy), "A Graded Approach for Evaluating Radiation Dose to Aquatic and Terrestrial Biota," DOE Technical Standard 1153-2002 (2002).

Honey Bees

by

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ABSTRACT

We collected honey bee samples from five hives placed downwind of the Dual-Axis Radiographic Hydrodynamic Test facility. Samples were analyzed for various radionuclides and trace elements and compared to baseline statistical reference levels (BSRLs). Most concentrations of radionuclides and all nonradionuclides were below the BSRLs. The only radionuclides that were above the BSRLs were those associated with U, particularly ^{238}U , and the ratios showed that the U was of depleted grade. All concentrations of U isotopes, however, were still very low and below terrestrial animal dose screening levels (<0.01 rad/d) and, therefore, not a significant hazard.

I. INTRODUCTION

As part of ongoing studies for the Mitigation Action Plan for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility (USDOE 1996), samples of honey bees were collected from beehives located near the facility during the summer of 2005. Honey bees can be thought of as mobile samplers that efficiently cover a large sample area and then return to a central location (Bromenshenk 1992). Honey bees forage in an area with a radius as large as 6 km and often cover a total area up to 100 square km (Leita et al., 1996; Visscher and Seeley 1982). Each hive contains hundreds of thousands of bees, and most of them will forage for nectar, water, pollen, and plant resins, which are all brought back into the hive. During these foraging flights, bees inadvertently contact and accumulate a wide array of pollutants, some of which are brought back to the hive (Bromenshenk et al., 1985). These contaminants often become incorporated into the bee tissue, the wax, the honey, or the hive itself (Wallwork-Barber et al., 1982). Honey bee studies have been conducted on many different types of pollutants including fluoride (Bromenshenk et al., 1988a; Mayer et al., 1988), Pb (Migula et al., 1989), Zn (Bromenshenk et al., 1988b), Ni (Balestra et al., 1992), K (Barbattini et al., 1991), and a variety of radionuclides (Hakonson and Bostick 1976; White et al., 1983; Bettoli et al., 1987; Tonelli et al., 1990; Fresquez et al., 1997).

The objective of this study was to compare various radionuclide and trace element concentrations in honey bees from around the DARHT facility with honey bees collected before

the start of operations (i.e., baseline data). Baseline statistical reference levels (BSRLs), which are defined as the mean concentration plus two standard deviations, were established over a four-year preoperational period (1997 through 1999) before DARHT facility operations and can be found in a report by Haarmann (2001).

II. METHODS

a. Bee Sampling

We monitored the DARHT facility using beehives consisting of a standard Langstroth hive stocked with Italian honey bees (*Apis mellifera ligustica*). Five hives were established at the study site approximately 100 m northeast, the predominant wind direction, of the DARHT facility (Figure 1).

In the summer of 2005, bee samples were collected from all of the hives. Five separate samples (one from each hive) were collected. An individual 100-g sample consists of approximately 1,000 bees. Individual frames were removed from the honey supers and bees were scraped off of the frames into large plastic bags and euthanized with liquid ether. The bee samples were transferred to a plastic resealable bag, weighed, and double bagged into plastic resealable bags. All samples were kept in a cooler and frozen upon returning to the laboratory.

b. Analytical Methods

Samples for ^3H analysis were placed in an apparatus to collect distillate water and transferred to labeled 10-mL polypropylene bottles. Approximately 10 g of whole bees were separated from each sample for trace element analysis and transferred to labeled 10-mL polypropylene bottles. The remaining portion of each sample was placed in 1-L glass beakers and ashed at 500 °C for 120 h, pulverized and homogenized after ashing, and transferred to labeled 500-mL polypropylene bottles. The distillate samples, whole tissue samples, and ash samples were submitted to Paragon Analytics, Inc., under chain of custody.

Paragon Analytics, Inc., analyzed the bee samples for radionuclides (^3H , ^{137}Cs , ^{241}Am , ^{234}U , ^{235}U , ^{238}U , ^{238}Pu , $^{239/240}\text{Pu}$, and ^{90}Sr) and trace elements (Ag, Ba, Be, Cd, Cr, Cu, Ni, Pb, Sb, Tl, As, Se, and Hg).

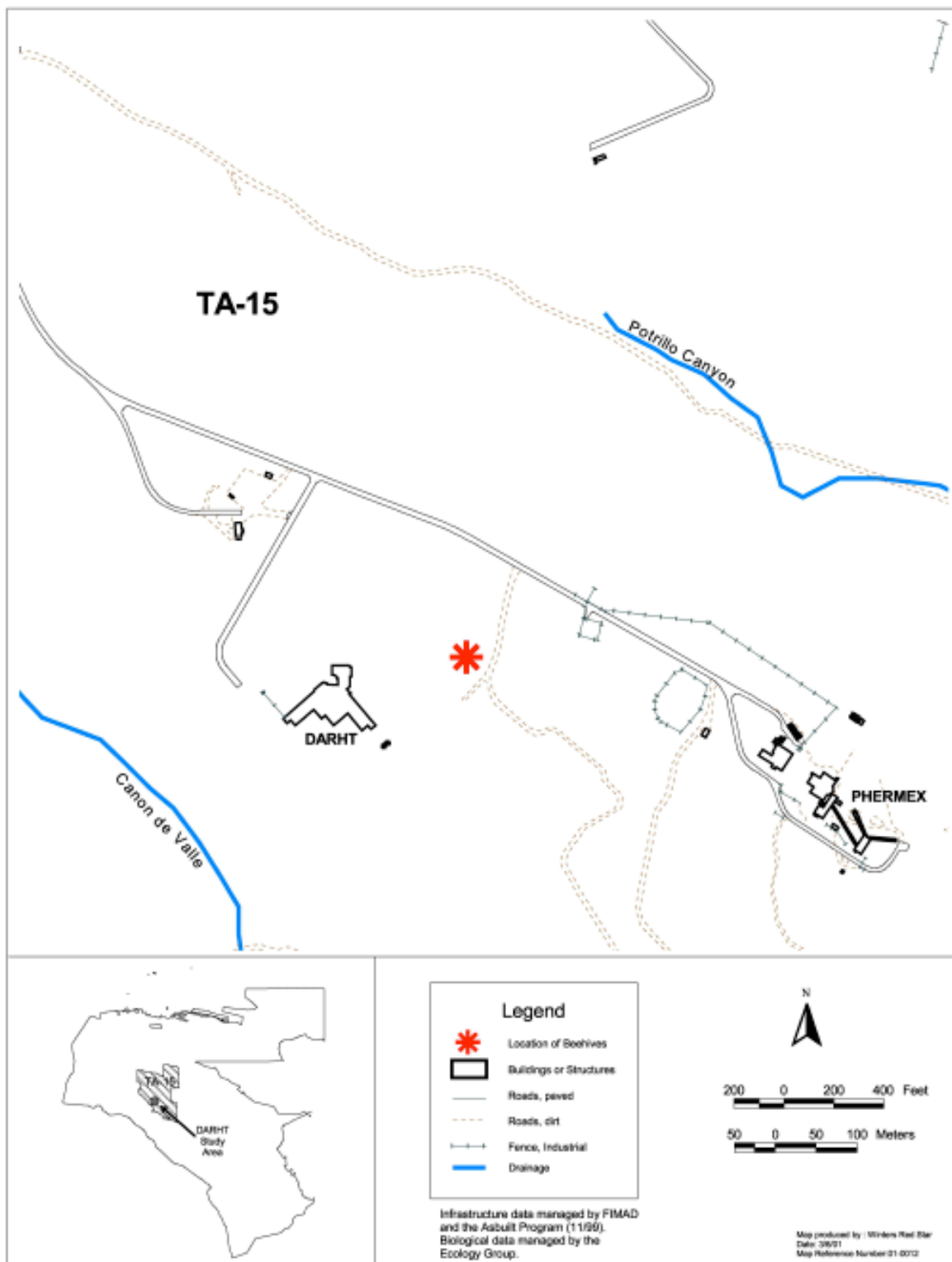


Figure 1. Location of the bee hives near DARHT.

c. Biota Standards

To evaluate DARHT facility impacts from radionuclides and nonradionuclides, the analytical results of bee samples collected from the facility are first compared to BSRLs. Where the levels exceed BSRLs, we then compare the concentrations to the screening levels (SLs). SLs are set below Federal Standards so that potential concerns may be identified in advance of problems (a “yellow flag”). If a constituent exceeds a SL, then the reason for that increase is more thoroughly investigated. For radionuclides in bees, the SLs were developed by the Meteorology and Air Quality Group dose assessment team to identify the contaminants of concern at 10% of the standard. For nonradionuclides in bees, the SLs are based on toxicity values from the literature. Finally, if a contaminant exceeds the SL then it is compared to the standard. For radionuclides in bees, the measured concentrations are used to calculate a dose according to USDOE (2002) and compare it with the 0.1-rad/d dose standard for terrestrial animals.

III. RESULTS

Analytical reports for individual sample assays are stored in the Meteorology and Air Quality Group database and are available upon request. Tables 1 and 2 contain a summary of the analytical results from samples collected near the DARHT facility. Most radionuclides were either at nondetectable concentrations (the results were below three times the analytical uncertainty) or below BSRLs. The only detectable radionuclides that were above the BSRLs were associated with U, particularly ^{238}U , and the ratio of ^{234}U to ^{238}U shows that the U is of depleted grade. All concentrations of U isotopes in bees at the DARHT facility, however, are below SLs (<204 pCi/g ash) and are not a significant hazard. Moreover, all of the metal concentrations in bees collected around the facility were below the BSRLs. The results are consistent with previous years.

Table 1. Radionuclide Concentrations and Analytical Uncertainties at three sigma in Honey Bees Collected from Hives near DARHT in 2005 (Note: Detectable concentrations exceeding the BSRL are in bold).

Radionuclide	Hive 1	AU ^a	Hive 2	AU	Hive 3	AU	Hive 4	AU	Hive 5	AU	BSRL ^b
³ H (pCi/mL)	0.60	0.47	0.55	0.42	0.43	0.35	0.31	0.34	0.45	0.35	4.5
¹³⁷ Cs	-0.3	2.3	0.6	1.3	-1.4	2.3	-0.9	1.1	0.04	0.63	4.1
(pCi/g ash)											
²⁴¹ Am	0.0011	0.0082	0.0037	0.0043	0.0039	0.0073	0.0060	0.0073	-0.0006	0.0062	0.038
(pCi/g ash)											
²³⁴ U	0.65	0.19	0.41	0.11	0.28	0.089	0.26	0.076	0.19	0.063	0.48
(pCi/g ash)											
²³⁵ U	0.045	0.035	0.036	0.020	0.038	0.024	0.041	0.021	0.018	0.016	0.025
(pCi/g ash)											
²³⁸ U	3.2	0.81	2.3	0.58	2.0	0.50	1.5	0.37	1.0	0.27	1.3
(pCi/g ash)											
Total U	9.6	2.4	7.0	1.7	5.9	1.5	4.5	1.1	3.1	0.81	3.9
(ug/g ash)											
^{239/240} Pu	0.003	0.012	0.0032	0.0048	0.0023	0.0084	0.0062	0.0075	0.0024	0.0064	0.097
(pCi/g ash)											
²³⁸ Pu	0.0	0.012	0.0006	0.0048	0.0023	0.0084	0.0008	0.0057	0.0016	0.0076	0.027
(pCi/g ash)											
⁹⁰ Sr	0.30	0.15	0.22	0.087	0.41	0.16	0.30	0.11	0.28	0.11	4.7
(pCi/g ash)											

^a Analytical uncertainty.

^b The BSRL for the U isotopes was calculated from total U using depleted U conversions.

**Table 2. Trace Element Concentrations (mg/kg wet) in Honey Bees Collected from Hives near DARHT in 2005
(Note: Detectable concentrations exceeding the BSRL are in bold.)**

Element	Hive 1	Hive 2	Hive 3	Hive 4	Hive 5	Reporting Limit	BSRL
Ba	2.3	2.9	1.6	1.8	1.5	0.033	4.1
Be	U ^a	U	U	U	U	0.017	
Cr	0.12	0.16	0.12	0.12	0.11	0.083	0.59
Cu	6.5	6.9	7.6	7.2	7.4	0.033	9.9
Ni	0.13	0.15	0.16	0.093	0.14	0.083	2.6
Sb	U	U	U	U	U	0.005	
As	U	U	U	U	U	0.033	
Cd	0.031	0.026	0.028	0.016	0.014	0.005	0.66
Pb	0.06	0.028	0.04	0.023	0.02	0.0083	3.0
Se	0.097	0.084	0.077	0.10	0.09	0.017	1.2
Ag	U	U	U	U	U	0.0017	
Tl	U	U	U	U	U	0.0033	
Hg	U	U	U	U	U	0.0099	

^aU = undetectd; an analyte was analyzed but was not detected above the reporting limit.

REFERENCES

- Balestra, V., G. Celli, and C. Porrini, "Bees, Honey, Larvae, and Pollen in Biomonitoring of Atmospheric Pollution," *Aerobiologia* 8:122–126 (1992).
- Barbattini, R., F. Frilli, M. Iob, C. Giovani, and R. Padovani, "Transfer of Cesium and Potassium by the 'Apiarian Chain' in Some Areas of Friuli [NE Italy]," *Apicoltura* 7:85–87 (1991).
- Bettoli, M.G., A.G. Sabatini, and M.A. Vecchi, "Honey Produced in Italy Since the Chernobyl Incident," *Apitalia* 14(10):5–7 (1987).
- Bromenshenk, J.J., "Site-Specific and Regional Monitoring with Honey Bees: Case Study Comparisons," in *Proc. of Int. Symp. on Ecological Indicators*, Volume 39, Fort Lauderdale, FL, 16–19 Oct. 1990. Elsevier Sci. Publ. London, UK (1992).
- Bromenshenk, J.J., S.R. Carlson, J.C. Simpson, and J.M. Thomas, "Pollution Monitoring of Puget Sound with Honey Bees," *Science* 227:800–801 (1985).
- Bromenshenk, J.J., R.C. Cronn, J.J. Nugent, and G.J. Olbu, "Biomonitoring for the Idaho National Engineering Laboratory: Evaluation of Fluoride in Honey Bees," *American Bee Journal* 128(12):799–800 (1988a).
- Bromenshenk, J.J., J.L. Gudatis, R.C. Cronn, J.J. Nugent, and G.J. Olbu, "Uptake and Impact of Heavy Metals to Honey Bees," *American Bee Journal* 128(12):800–801 (1988b).
- Fresquez, P.R., D.R. Armstrong, and L.H. Pratt, "Radionuclides in Bees and Honey Within and Around Los Alamos National Laboratory," *J. Environ. Sci. Health* A32(5):1309–1323 (1997).
- Haarmann, T.K., "Baseline Concentrations of Radionuclides and Heavy Metals in Honey Bee Samples Collected Near the DARHT Facility during 1997–1999," pp. 63–75 in Nyhan, J.W., P.R. Fresquez, K.D. Bennett, T.K. Haarmann, D.C. Keller, J.R. Biggs, and H.T. Haagenstad, "Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees Around the DARHT Facility: Construction Phase (1996 through 1999)," Los Alamos National Laboratory report LA-13808-MS (2001).
- Hakonson, T.E., and K.V. Bostick, "The Availability of Environmental Radioactivity to Honey Bee Hives at Los Alamos," *J. Environ. Qual.* 5(3):307–309 (1976).
- Leita, L., G. Muhlbachova, S. Cesco, R. Barbattini, and C. Mondini, "Investigation of the Use of Honey Bees and Honey Bee Products to Assess Heavy Metals Contamination," *Environmental Monitoring and Assessments* 43:1–9 (1996).
- Mayer, D.G., I.D. Lunden, and L.H. Weinstein, "Evaluation of Fluoride Levels and Effects on Honey Bees (*Apis mellifera* L.)," *Fluoride* 21:113–120 (1988).
- Migula, P., K. Binkowska, A. Kafel, and M. Nakonieczny, "Heavy Metal Contents and Adenylate Energy Charge in Insects from Industrialized Region as Indices of Environmental Stress," in *Proceedings of the 5th International Conference*,

Bioindicatores Deteriorationis Regionis, II. Ceske Budejovice, Czechoslovakia: Institute of Landscape Ecology (1989).

Tonelli, D., E. Gattavecchia, S. Ghini, C. Porrini, G. Celli, and A.M. Mercuri, "Honey Bees and Their Products as Indicators of Environmental Radioactive Pollution," *Journal of Radioanalytical and Nuclear Chemistry* 141(2):427–436 (1990).

USDOE (US Department of Energy), "Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement Mitigation Action Plan," United States Department of Energy report USDOE/EIS-0228 (1996).

USDOE (US Department of Energy), "A Graded Approach for Evaluating Radiation Dose to Aquatic and Terrestrial Biota," DOE Technical Standard 1153-2002 (2002).

Visscher, P.K., and T.D. Seeley, "Foraging Strategy of Honey Bee Hives in a Temperate Deciduous Forest," *Ecology* 63:1790–801 (1982).

Wallwork-Barber, M.K., R.W. Ferenbaugh, and E.S. Gladney, The Use of Honey Bees as Monitors of Environmental Pollution," *American Bee Journal* 122(11):770–772 (1982).

White, G.C., T.E. Hakonson, and K.V. Bostick, "Fitting a Model of Tritium Uptake by Honey Bees to Data," *Ecological Modelling* 18(3/4):241–251 (1983).

**Bird Monitoring
Near DARHT in 2003, 2004, and 2005**

by

D.C. Keller

ABSTRACT

In 2003, 2004, and 2005, birds were collected from netting locations at Los Alamos National Laboratory's Dual-Axis Radiographic Hydrodynamic Test facility. In 2003, 164 birds were captured representing 29 species. In 2004, we captured 126 birds from 28 species, and in 2005 we captured 412 birds from 46 species.

I. INTRODUCTION

In 1997 biologists from the Ecology Group (ENV-ECO) began to operate a Monitoring Avian Population and Survivorship (MAPS) station just to the north and west of the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility. The purpose of this station was to monitor long-term bird populations around the DARHT facility for population dynamics and survivorship information. The population information takes a minimum of five consecutive years to begin to develop trends in population and survivorship. We have also collected contaminant information on birds over the DARHT preoperational and postoperational periods. In next year's report, the contaminant results for 2003–2005 will be included.

II. METHODS

Biologists erected a series of 13 bird mist nets in the forest to the north and west of the DARHT facility (Figure 1). The nets are generally placed in a one-mile line transect along the edge of Cañon de Valle and the confluence of Water Canyon. ENV-ECO operates the nets by the MAPS standard of one netting day each 10 days from May through August. Each net is 12 m long and 3 m high. These nets are stretched between two poles in areas with good bird habitat. The nets are opened at first light and remain open for at least six hours. Nets are checked for birds at approximately quarter- to half-hour intervals. Basic physical measurements are recorded for each captured bird and they

are banded with a US Fish and Wildlife Service band. The measurements include wing and tarsus length and total body weight. We also note any unusual characteristics. Each bird has its age determined based on feather molt characteristics developed by Pyle (1997). A species that has not been captured before is photographed for later reference.



Figure 1. DARHT net locations.

III. RESULTS

During the 2003 field season, 164 birds were captured from 29 species (Table 1). The western bluebird (*Sialia mexicana*) and the chipping sparrow (*Spizella passerina*) were the most commonly captured species.

During the 2004 field season, 126 birds were captured from 28 species (Table 2). The chipping sparrow, the broad-tailed hummingbird (*Selasphorus platycercus*), and Virginia's warbler (*Vermivora virginiae*) were the most commonly captured species.

During the 2005 field season, 412 birds were captured from 46 species (Table 3). The most abundant species was the western tanager (*Piranga ludoviciana*) with all 102 of the birds having been caught in one day. The next abundant species included the Virginia's warbler, the chipping sparrow, and the Audubon's warbler form of the yellow rumped warbler (*Dendroica coronata*).

ACKNOWLEDGMENTS

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REFERENCES

Pyle, P., *Identification Guide to North American Birds*, Slate Creek Press (1997).

Table 1. Birds Captured in 2003

Species Alpha Code	Species	Total	Relative Abundance	Species Alpha Code	Species	Total	Relative Abundance
ATFL	Ash Throated Flycatcher	5	3.05%	MOBL	Mountain Bluebird	6	3.66%
BEWR	Bewick's Wren	5	3.05%	MOCH	Mountain Chickadee	2	1.22%
BGGN	Blue-Gray Gnat Catcher	2	1.22%	NOFI	Northern Flicker	1	0.61%
BHGR	Black-headed Grosbeak	1	0.61%	RCKI	Ruby-Crowned Kinglet	1	0.61%
BRHU	Broadtail Hummingbird	11	6.71%	RUHU	Rufous Hummingbird	2	1.22%
CHSP	Chipping Sparrow	19	11.59%	SAGS	Sage Sparrow	13	7.93%
COBU	Common Bushtit	7	4.27%	SOVI	Solitary Vireo	3	1.83%
GRFL	Gray Flycatcher	8	4.88%	SPTO	Spotted Towhee	6	3.66%
HAWO	Hairy Woodpecker	6	3.66%	VIWA	Virginia Warbler	3	1.83%
HETH	Hermit Thrush	3	1.83%	WBNU	White Breasted Nuthatch	2	1.22%
HOFI	House Finch	7	4.27%	WEBL	Western Bluebird	21	12.80%
HOWR	House Wren	1	0.61%	WETA	Western Tanager	4	2.44%
JUTI	Juniper Titmouse	14	8.54%	WEWP	Western Wood-Pee wee	5	3.05%
LEGO	Lesser Goldfinch	3	1.83%	YRWA	Yellow Rumped Warbler	2	1.22%
MGWA	MacGillivray's Warbler	1	0.61%				
TOTAL				164		100.00%	

Table 2. Birds Captured in 2004

Species Alpha Code	Species Name	Total	Relative Abundance	Species Alpha Code	Species Name	Total	Relative Abundance
ATFL	Ash-throated Flycatcher	3	2.38%	PYNU	Pygmy Nuthatch	5	3.97%
AUWA	Audubon Warbler	1	0.79%	ROWR	Rock Wren	10	7.94%
BRCR	Brown Creeper	1	0.79%	RUHU	Rufus Hummingbird	1	0.79%
BRHU	Broadtail Hummingbird	16	12.70%	SAPH	Say's Phoebe	3	2.38%
CAKI	Cassin's Kingbird	1	0.79%	SASP	Sage Sparrow	3	2.38%
CANR	Canyon Wren	1	0.79%	SCJA	Scrub Jay	1	0.79%
CHSP	Chipping Sparrow	18	14.29%	SPTO	Spotted Towhee	3	2.38%
DUFL	Dusky Flycatcher	1	0.79%	TOSO	Town Solitaire	2	1.59%
HAWO	Hairy Woodpecker	2	1.59%	VGSW	Violet-green Swallow	1	0.79%
HOFI	House Finch	4	3.17%	VIWA	Virginia's Warbler	13	10.32%
JUTI	Juniper Titmouse	1	0.79%	WBNU	White-breasted Nuthatch	6	4.76%
LEGO	Lesser Gold Finch	4	3.17%	WEBL	Western Bluebird	9	7.14%
MOBL	Mountain Bluebird	3	2.38%	WETA	Western Tanager	5	3.97%
MOCH	Mountain Chickadee	1	0.79%	WEWP	Western Wood-Pewee	7	5.56%
TOTAL			126			100.00%	

Table 3. Birds Captured in 2005

Species Alpha Code	Species	TOTAL	Relative Abundance	Species Alpha Code	Species	TOTAL	Relative Abundance
AMRO	American Robin	1	0.24%	MOCH	Mountain Chickadee	5	1.21%
ATFL	Ash-throated Flycatcher	3	0.73%	RSFL	Northern Flicker	1	0.24%
AUWA	Audubon's Warbler	28	6.80%	OCWA	Orange-crowned Warbler	2	0.49%
BHGR	Black-headed Grosbeak	9	2.18%	PISI	Pine Siskin	2	0.49%
BGGN	Blue-gray Gnatcatcher	2	0.49%	PLVI	Plumbeous Vireo	2	0.49%
BTLH	Broad-tailed Hummingbird	13	3.16%	PYNU	Pygmy Nuthatch	1	0.24%
BRCR	Brown Creeper	2	0.49%	ROWR	Rock Wren	24	5.83%
CANT	Canyon Towhee	1	0.24%	RCKI	Ruby-crowned Kinglet	1	0.24%
CANW	Canyon Wren	4	0.97%	RUHU	Rufous Hummingbird	9	2.18%
CHSP	Chipping Sparrow	31	7.52%	SAGS	Sage Sparrow	18	4.37%
COPO	Common Poorwill	1	0.24%	SPTO	Spotted Towhee	9	2.18%
COFL	Cordilleran Flycatcher	4	0.97%	TOSO	Townsend's Solitaire	3	0.73%
DUFL	Dusky Flycatcher	3	0.73%	VESP	Vesper Sparrow	1	0.24%
GRFL	Gray Flycatcher	3	0.73%	VGSW	Violet-green Swallow	2	0.49%
GTTO	Green-tailed Towhee	3	0.73%	VIWA	Virginia's Warbler	33	8.01%
GHJU	Grey-headed Junco	14	3.40%	WEBL	Western Bluebird	20	4.85%
HAWO	Hairy Woodpecker	7	1.70%	WESJ	Western Scrub-Jay	1	0.24%
HETH	Hermit Thrush	3	0.73%	WETA	Western Tanager	102	24.76%
HOFI	House Finch	12	2.91%	WWPE	Western Wood-Pewee	7	1.70%
JUTI	Juniper Titmouse	4	0.97%	WBNU	White-breasted Nuthatch	8	1.94%
LEGO	Lesser Goldfinch	3	0.73%	WISA	Williamson's Sapsucker	1	0.24%
MGWA	MacGillivray's Warbler	1	0.24%	WIWA	Wilson's Warbler	5	1.21%
MOBL	Mountain Bluebird	2	0.49%	YWAR	Yellow Warbler	1	0.24%
TOTAL			412			100.00%	

The Effects of Discontinuity in Sample Data

by

G.J. Gonzales

ABSTRACT

We considered and analyzed the effects of discontinuity in sample data on use of the data and on ability to meet the intent of the Mitigation Action Plan (MAP). We analyzed postoperational radionuclide data for statistical differences between years and, for media where data has been collected in more than one location, we also analyzed statistical differences between locations. As a measure of whether substantial differences might exist in outcomes of using the data from different media, we also estimated radiation dose to the Mexican spotted owl that could result from using two different starting points (or contaminant sources) in the food pathway leading to the owl: (1) radionuclide concentrations in deer mice and (2) radionuclide concentrations in understory vegetation. On the basis of the spatial/temporal comparisons and dose estimates, periodic interruption of the schedule identified in the MAP generally should have no impact on meeting the intent of the MAP. Based on additional criteria, it is most important to continue sampling soils, vegetation, and small mammals yearly. The large home range of bees conveys information on contaminant levels over a much broader area than most of the other sampling media. The risk of not sampling one of the five media in any given year is that, if a significant impact to contaminant levels were to occur, there would exist a less complete understanding of the extent of the change to the baseline for these media and to the ecosystem as a whole. Since the MAP is a requirement that was established under the regulatory framework of the National Environmental Policy Act, any changes to the monitoring requirements in the MAP must be negotiated and ultimately approved by the U.S. Department of Energy.

I. INTRODUCTION

As a component of the Mitigation Action Plan (MAP) for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility, the Los Alamos National Laboratory (LANL) has been measuring radionuclide concentrations in five environmental media (soil, plants, bees, birds, and small mammals) around the DARHT

facility since 1996. Up to four years (1996–1999) of preoperational baseline data have been collected and up to six years (2000–2005) of postoperational data have been collected (Table 1). Because interruptions have occurred in the collection of samples of some of the media for various reasons, DARHT facility project managers were interested in knowing the effects of discontinuity in the sample data on the use of the data and on ability to meet the intent of the MAP. The DARHT facility MAP requires collection of data on the five media each year for the 30-year estimated life of the DARHT facility. We analyzed postoperational radionuclide data for statistical differences between years and, for media where data has been collected in more than one location, we also analyzed for statistical differences between locations. As a measure of whether substantial differences might exist in outcomes of using the data from different media, we also estimated dose to the Mexican spotted owl that could result from using two different starting points (or contaminant sources) in the food pathway leading to the owl: (1) beginning with radionuclide concentrations in deer mice versus (2) beginning with radionuclide concentrations in understory vegetation.

Table 1. Media Sampling Occurrences by Year for the DARHT Facility Conducted Under the MAP

	Preoperations				Postoperations					
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Soils	x	x	x	x	x	x	x	x	x	x
Vegetation	x	x	x	x	x	x	x	x	x	x
Small Mammals	x	x	x	x		x	x	x		
Birds	x	x	x	x			x	x	x	x
Bees	x	x	x	x	x	x	x	x		x

II. METHODS

Concentrations of radionuclides in each media were compared between locations and between years using parametric and nonparametric statistics.

Calculations of doses to predators were made using the following equations (LANL 2004):

$$\text{Dose} = \text{Body burden in predator} \times \text{Dose conversion factor}$$

$$\text{Body burden} = \text{Concentration in food} \times \text{Ingestion rate of food} \times \text{Food to predator transfer factor} \times \text{Retention time}$$

where,

$$\text{Dose} = \text{rad} \cdot \text{day}^{-1}$$

$$\text{Body burden} = \text{pCi} \cdot (\text{g BW})^{-1}$$

BW = fresh tissue mass of the predator

$$\text{Dose conversion factor} = \text{rad} \cdot \text{day}^{-1} \cdot (\text{pCi} \cdot [\text{g BW}]^{-1})^{-1}$$

$$\text{Concentration in food} = \text{pCi} \cdot (\text{g FF})^{-1}$$

FF = fresh tissue mass of the food

$$\text{Ingestion rate} = (\text{g FF}) \cdot \text{g BW}^{-1} \cdot \text{day}^{-1}$$

Transfer factor = unitless

Retention time = days

The values for the input parameters in the equations were derived from the following:

- literature values for predator body weights and prey ingestion rates,
- average measured concentrations in prey from cited references,
- fractional food to tissue transfer factors from the Laboratory's dose assessment methodology (LANL 2002),
- dose conversion factors assuming 100% deposition of decay product energy in the predator's body (USDOE 2000), and
- radionuclide retention time based on radiological and biological half-lives and estimated life spans (LANL 2002, 2004).

III. RESULTS

Tables 2 and 3 show results of parametric statistical tests for difference in time and between sampling locations. Considering radionuclide concentrations in the five media, generally few statistical differences were detected between locations and years, although the statistical robustness was low as a result of small sample sizes.

Radionuclide activity concentrations in soil mostly were not significantly different between years nor between locations, however, there were some differences. Significant differences were detected between years for ^{137}Cs and ^3H and between locations for total U. For all radionuclides, the mean probability of no differences across years was 0.24. For all radionuclides, the mean probability of no differences between locations was 0.38.

When compared across years and sampling locations, radionuclide activity concentrations in understory vegetation were not significantly different ($\alpha = 0.01$). Of seven radionuclides, when concentrations in overstory vegetation were compared across years and sampling locations only one, ^{90}Sr , showed a statistically significant difference ($P = 0.007$) between locations, but the F-statistic was only slightly above the critical F value at $\alpha = 0.01$.

Table 2. Results of Analysis of Variance Tests for Significance of Differences in Mean Radionuclide Concentrations Between Years

	^{241}Am	^{137}Cs	^3H	^{238}Pu	^{239}Pu	^{90}Sr	Total U
Soil	NS P = 0.77	Sig P = 0.009	Sig P < 0.01	NS P = 0.07	NS P = 0.10	NS P = 0.05	NS P = 0.22
Understory Vegetation	NS P = 0.61	NS P = 0.96	NS P = 0.18	NS P = 0.62	NS P = 0.56	NS P = 0.61	NS P = 0.28
Overstory Vegetation	NS P = 0.78	NS P = 0.60	NS P = 0.18	NS P = 0.17	NS P = 0.63	NS P = 0.22	NS P = 0.21
Bees	NS P = 0.41	NS P = 0.14	NS P = 0.10	NS P = 0.09	NS P = 0.62	NS P = 0.56	
Birds*	N/A	N/A	N/A	N/A	N/A	N/A	
Small Mammals	NS P = 0.30	NS P = 0.71	Sig P = 0.01	NS P = 0.35	NS P = 0.54	NS P = 0.15	NS P = 0.39

*Only one composite sample was collected in 2003 and 2004, therefore statistical analyses were not performed.

Table 3. Results of Analysis of Variance Tests for Significance of Differences in Mean Radionuclide Concentrations Between Sampling Locations

	^{241}Am	^{137}Cs	^3H	^{238}Pu	^{239}Pu	^{90}Sr	Total U
Soil	NS P = 0.25	NS P = 0.16	NS P = 0.78	NS P = 0.72	NS P = 0.15	NS P = 0.21	Sig P = 0.01
Understory Vegetation	NS P = 0.71	NS P = 0.89	NS P = 0.99	NS P = 0.51	NS P = 0.90	NS P = 0.38	NS P = 0.46
Overstory Vegetation	NS P = 0.59	NS P = 0.61	NS P = 0.47	NS P = 0.91	NS P = 0.26	Sig P = 0.007	NS P = 0.07
Bees	NS P = 0.74	NS P = 0.74	NS P = 0.68	NS P = 0.64	NS P = 0.39	NS P = 0.46	
Birds*	N/A	N/A	N/A	N/A	N/A	N/A	
Small Mammals	NS P = 0.64	NS P = 0.52	NS P = 0.27	NS P = 0.67	NS P = 0.98	NS P = 0.82	NS P = 0.63

*Only one composite sample was collected in 2003 and 2004, therefore statistical analyses were not performed.

Radionuclide concentrations in small mammals (deer mice) were, by and large, no different across years nor locations. Comparing 2001–2003 and three sampling locations, only ^3H was statistically different between years with a $P = 0.01$. For all radionuclides, the mean probability of no differences across years was 0.44. For all radionuclides, the mean probability of no differences between locations was 0.63.

When compared across years and colonies, radionuclide activity concentrations in honey bees were not significantly different ($\alpha = 0.01$). Across all radionuclides, the mean probability of no differences across years was 0.26. Across all radionuclides, the mean probability of no differences between colonies was 0.61.

Using mean concentrations of radionuclides in deer mice, which are prey to the Mexican spotted owl, the estimated dose to the owl was $1.38\text{E-}07$ rad/day. In comparison, starting at a lower trophic level in the food chain of the owl—mean radionuclide concentrations in understory vegetation—the estimated dose to the owl was $2.43\text{E-}06$ rad/day. Given the U.S. Department of Energy dose limit of 0.1 rad/day, we consider the difference in estimated dose to the owl resulting from the two different starting points (or position in the food chain) to be insignificant.

IV. DISCUSSION

In both understory and overstory vegetation, radionuclide activity concentrations vary little from year to year and between locations. Although estimated dose to the Mexican spotted owl beginning at two different trophic levels in the food chain of the owl resulted in a difference of about an order of magnitude, the dose is so small in comparison to the dose standard that we consider the difference in dose estimates to be insignificant. Doses to higher-level predators can be estimated from one source without fear of grossly misrepresenting doses that might occur from other sources. So, if any given media was not sampled in a given year, this use of data—dose estimation—would not be affected to an extent that the outcome would change.

There are other factors to consider when evaluating the role and value of each media in meeting the intent of the MAP. These factors are (1) the role of a media in the ecosystem, (2) usability of data, and (3) ease of collection and continuity of data. Soil acts as an integrating medium that can account for contaminants released to the

environment. A soil-sampling and analysis program provides the most direct means of determining the inventory, concentration, distribution, and long-term buildup of radionuclides and other contaminants around nuclear facilities. The knowledge gained from a soil-sampling program is important for providing information about potential pathways, such as soil ingestion, food crops, resuspension into the air, and contamination of groundwater, that may result in a radiation or chemical dose to plants, animals, or humans. Soil sampling is relatively easy and the continuity of soil sampling at the DARHT facility has been consistent as shown in Table 1. Soil sampling has been conducted in years of drought, natural disasters such as wildfire, or other events that add to the difficulty of conducting the sampling required by the MAP.

Vegetation is the foundation of ecosystems as it provides the initial usable form of energy and nutrients that are transferred through food chains. Because of this function in the food chain, vegetation can serve as an important pathway of contaminants to biological systems. Vegetation sampling is relatively easy and the continuity of vegetation sampling at the DARHT facility has been consistent as shown in Table 1.

Probably the most significant factor in the decision to prepare an Environmental Impact Statement and MAP on the DARHT facility in the 1990s before LANL was allowed to continue construction of the facility was the discovery of Mexican spotted owls in the vicinity. Small mammals by far dominate the diet of the owl. As such and since greater protection is afforded federally protected species than others, it is important to continue monitoring contaminant levels in small mammals as uninterrupted as possible.

Birds and bees constitute important potential contaminant pathways in an ecosystem that are different than pathways that involve small mammals, however their importance to protection of the Mexican spotted owl is relatively much less than that of small mammals. The large home range of bees (up to 100 km²) conveys insight into contaminant levels over a much broader area spatially than most of the other sampling media. While this large of a home range likely conveys contaminant exposure information beyond the DARHT facility as a source, it is realistic that many organisms experience cumulative exposures that are the result of more than one source.

It is important to net and mark bird populations near the DARHT facility each year to maintain the ability to calculate population trends and survivorship of the populations. Calculations require at least five years of uninterrupted netting to perform the necessary statistics to estimate population and survivorship. Yearly netting data enables the determination of changes in local populations in comparison with other areas, which allows us to assess whether DARHT is influencing the bird populations uniquely. This, in turn, provides LANL with the information that would be necessary to design mitigation measures for perturbations. The development of mitigation measures and resulting actions that protect wildlife populations completes the process required by the National Environmental Policy Act (NEPA).

V. CONCLUSIONS

On the basis of the spatial/temporal comparisons and dose estimates, periodic interruption of the scope and schedule identified in the MAP generally should have no impact on meeting the intent of the MAP. Based on additional criteria previously discussed, it is most important to continue sampling soils, vegetation, and small mammals yearly. The other two media—bees and birds—also provide uniquely important information. The risk of not sampling one of the five media in any given year is that if a significant impact to contaminant levels were to occur there would exist a less complete understanding of the extent of the change to the baseline for these media and to the ecosystem as a whole. Since the MAP is a requirement that was established under the regulatory framework of NEPA, any changes to the monitoring requirements in the MAP must be negotiated with and ultimately approved by the U.S. Department of Energy.

REFERENCES

LANL (Los Alamos National Laboratory), “Screening-Level Ecological Risk Assessment Methods, Revision 2,” Los Alamos National Laboratory document LA-UR-04-8246, Los Alamos, New Mexico (2004).

LANL (Los Alamos National Laboratory), “ECORISK Database (Revision 1.4),” Environmental Restoration package 186, Los Alamos National Laboratory, Los Alamos, New Mexico (2002).

USDOE (United States Department of Energy), 2000, “A Graded Approach for Evaluating Radiation Dose to Aquatic and Terrestrial Biota,” Department of Energy

Technical Standard ENR-011. (2000) [available at <http://homer.ornl.gov/oepa/public/bdac>].

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